Advanced Flicker Spectroscopy of Fluid Membranes

Daniel Kroll, University of Minnesota, Minneapolis, DMR-0083219

Membranes composed of amphiphilic molecules are very flexible, nearly tensionless surfaces. The morphology of a membrane is determined by its elastic bending energy, and the parameters characterizing this energy are the bending rigidity, κ, which sets the energy scale, and the spontaneous curvature, c_o, which describes the preferred curvature of the membrane. In addition to playing a key role in determining the morphology of biomembranes, lipid vesicles, and polymersomes, c_o is crucial for maintaining the spatial organization of, and traffic between, cellular organelles and the plasma membrane. More generally, control of interfacial curvature is require to tune the structure of materials on the nanoscale.

A fundamental problem in soft matter physics is to develop a method for determining c_o experimentally. We have developed a new technique which utilizes extensive Monte Carlo simulations of dynamically triangulated vesicles to generate data for a wide range of reduced volumes, bending rigidities, and spontaneous curvatures which are then used to extract the elastic parameters from flicker spectroscopy data.

Using this technique, it was possible, for the first time, to simultaneously determine both elastic parameters in a single experiment and study their dependence on environmental conditions, such as temperature and solvent pH.

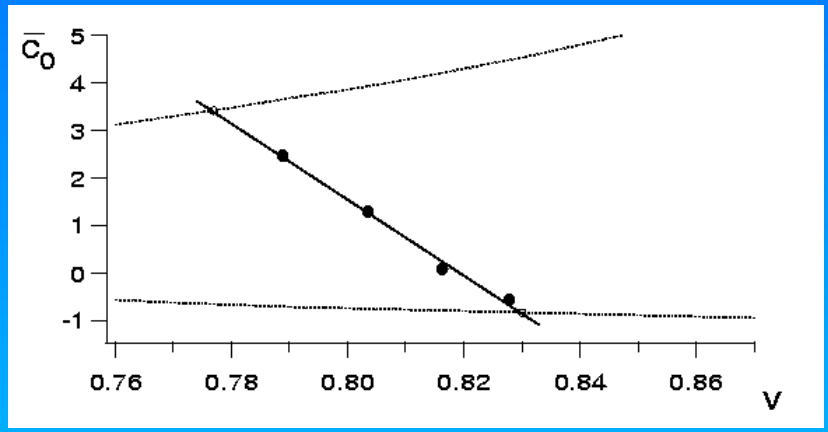

Figure 1. Thermal trajectories of a prolate SOPC (Stearoyl-Oleoyl-Phosphatidylcholin) vesicle in the c_0, reduced volume, v (where v=1 for a sphere), parameter space. The experimental data points correspond to temperatures T=25.0, 29.4, 34.2, and 38.8 ^oC. The crossing points of a linear fit to the trajectory with the upper (budding) and lower (prolate-oblate) spinodals are indicated. The fits give a value $\kappa = 35 \pm 3$ kT for the bending rigidity, in good agreement with the value 32 kT reported elsewhere. The dotted spinodals are results of a T=0 shape calculation.

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•Method can be extended to aid in monitoring bio-chemical reactions at interfaces, model the bio-manipulation of cells, and support future experimental studies of biological and material aspects of interfacial elasticity.
•A software package will be made available to enable similar analyses in other labs.

Collaborators:

H.-G. Doebereiner, MPI Golm, Germany
G. Gompper, IFF der KFA Juelich, Germany
C.K. Haluska, MPI Golm, Germany
P.G. Petrov, University of Exeter, England
K.A. Riske, MPI Golm, Germany

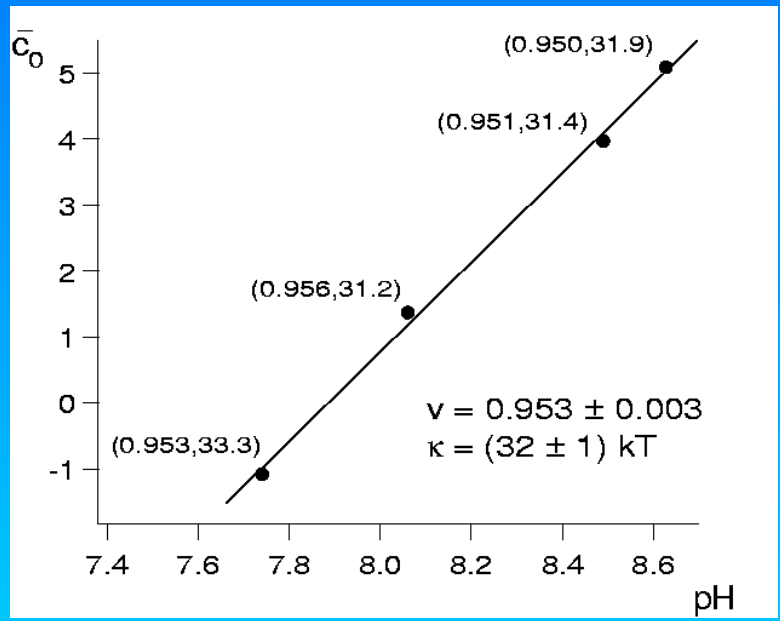

Figure 2. Determination of electrostatically induced spontaneous curvature in a zwitterionic membrane as a function of the external solution pH. Fits yielded the values for v and κ quoted in brackets. Since each data point was fitted independently, the fact that constant values for v and κ were obtained is a non-trivial test of the method.